# National Bureau of Standards

## TECHNICAL NEWS BULLETIN

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# Hydraulic-Turbine Dental Handpiece

## a high-speed cutting tool free of vibration and excess heating

A HYDRAULIC-TURBINE dental handpiece which attains a speed of 61,000 revolutions per minute has been developed at the National Bureau of Standards. At this speed, very low cutting pressure is required and dental enamel can be cut rapidly with a minimum of vibration and heating. By positioning the turbine in the head of the handpiece and connecting it directly to the cutting tool, the mechanical difficulties involved in the use of high rotational speeds with the conventional belt-and-gear propelled cutting tools have been eliminated. Besides making possible more efficient cutting of tooth structures and reducing the time spent by the patient in the dental chair, the hydraulic-turbine handpiece also promises to be of considerable utility in other fields where small amounts of hard materials must be removed by grinding, as in tool and die making.

The hydraulic handpiece was designed and constructed by Dr. R. J. Nelsen, of the American Dental Association Research Fellowship at the Bureau, and C. E. Pelander and J. W. Kumpula of the NBS staff. The project was part of a program of dental research which NBS is conducting in cooperation with the American Dental Association and the dental services of the Army, the Air Force, the Navy, and the Veterans' Administration.

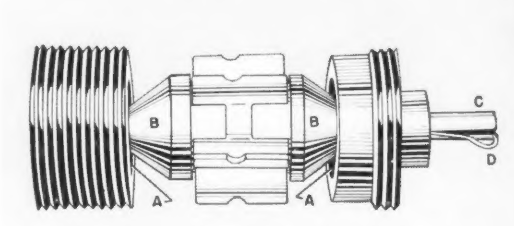
At present the maximum speed of conventional dental cutting instruments is about 6,500 rpm. Because of the small size of dental burs, this rate of rotation gives too low a linear speed for efficient cutting of tooth structures. For example, a steel bur can remove the same amount of material in 4 seconds at 12,000 rpm as it can in approximately 30 seconds at 2,000 rpm.[1] However, in spite of the disadvantages of using low rotational speeds, dentists have hesitated to use higher speeds with the conventional gear-type handpiece because of the excessive vibration and heat developed and the potential hazard to the patient caused by the high inertia of the revolving instrument.

Several types of dental rotary cutting instruments using air or water as the motive power have been constructed in the past, but each of these was designed for the straight dental handpiece, and each required that a gear-type contra-angle handpiece be attached. The instrument developed at NBS is designed to completely eliminate gears within the handpiece since the turbine is placed in the head of the contra-angle. This makes it possible to overcome many of the disadvantages of high rotary speed in cavity preparation by taking advantage of the smoothness and other characteristics inherent in hydraulic systems. Thus, vibration is minimized; and the high-speed stream of fluid passing over the turbine and shaft acts as a coolant so that overheating is prevented in spite of the high rotational speed developed.

A further advantage of the hydraulic handpiece is that even while rotating at top speed, the cutting instrument can be stopped immediately by placing a finger

abruptly against its edge. Then, as soon as the disk is released, it will start rotating again. This means that if the operator should press too heavily on the cutting tool or if the tool should happen to catch or bind in some manner that would be hazardous with the ordinary handpiece, the hydraulic instrument will automatically stop rotating. Because of the extremely light pressures used for cutting, there is considerably less strain on the operator. Furthermore, the cutting tools do not climb or roll out of the cavity as do those used in the slower rotating instruments. While some adjustment in the dentist's operating procedure is necessary, the instrumentation is basically the same as his present methods, and therefore the dentist requires no special training in its use.

The overall size and shape of this handpiece are within the general proportions of the conventional gear-driven contra-angle handpiece. The turbine shaft is designed so that the hollow shaft of the cutting instrument fits over it. A spring key attachment on the turbine shaft fits into a keyway in the cutting-instrument shaft, and the centrifugal force developed by the rotating turbine causes this spring to lock the cutting instrument in place. When the shaft is still, the cutting instrument can be easily attached or removed.




***Top:* Evaluation of the high-speed dental handpiece as a tool in operative dentistry is being carried out at the Bureau with the cooperation of the American Dental Association. *Middle:* Comparative size and appearance of the hydraulic-turbine dental handpiece (top and center) and the conventional contra-angle handpiece (bottom) attached to a straight handpiece and wrist joint. *Bottom:* Turbine assembly of the high-speed dental handpiece. This model uses plastic bearings (A) and plastic journals (B). The turbine shaft (C) contains a spring key attachment (D) which engages a keyway on the shaft of the cutting tool.**

The turbine has six notched blades fixed to the shaft and measures 7.5 mm. in diameter and 4.8 mm in length. Although steel ball bearings have been used in some models, they are rather harsh and noisy in this application. Various combinations of low-friction plastic materials in bearings and journals have proved much more satisfactory as they are quieter in operation and do not require lubrication.

The associated hydraulic system consists of a mobile cabinet which contains a fluid pumping mechanism, a reservoir tank, a pressure switch, a solenoid valve, and distribution lines. The contra-angle handpiece is connected to a flexible coaxial double tubing. The 3/8-inch inside tube carries the propellent fluid (water) under pressure to the contra-angle handpiece while the 5/8-inch outer tube carries the spent fluid back to the reservoir. The tubes join with the direct line from the pump and the line to the reservoir tank. A constant-volume pump, close-coupled to a 1/2-horsepower electric motor, is used. To minimize undesirable motor noise, the pumping equipment is enclosed in a sound-insulated cabinet.

The unit is self-contained and needs only to be connected to an electrical outlet for operation. The fluid

is stored in the reservoir and is used over and over; hence the unit requires no adjustment during normal use. To stop the turbine momentarily, the operator steps on a special tube containing fluid. The force exerted closes a pressure switch, thus opening a solenoid valve which allows the propellent to pass the turbine and to return directly to the reservoir. While the instrument is being used, the motor and pump operate continuously and the handpiece is energized as needed by the operator. The motor is controlled by a switch located on the side of the unit.

Grinding tools such as points and disks of diamond and silicon carbide have been found to cut with exceptional efficiency when used with the hydraulic handpiece. However, milling cutters like the steel and carbide burs of current design do not function well at such extremely rapid rates of cutting. It is believed that the design of the cutting blades of all burs will have to be modified before they can be used at the rotational speeds of this handipiece.

*For further technical details, see* Hydraulic turbine contra-angle handpiece, *by Robert J. Nelsen, Carl E. Pelander, and John W. Kumpula. J. Am. Dental Assoc.* **47**, *324* (*1953*).

[1] Temperature developed in rotating dental cutting instruments, *by Donald C. Hudson and W. T. Sweeney, J. Am. Dental Assoc.* **48**, *127* (*1954*).

# Edge-Insulation Methods for Concrete-Slab Floors

IN RECENT YEARS there has been a great increase in the number of basementless houses constructed. The floor most generally used in this type of house is the concrete slab, sometimes placed on the ground but more often on a fill of gravel or similar material.

Because concrete is a good conductor of heat as compared to wood flooring, a concrete floor will be relatively cool in the region near the outside walls in cold weather, often making it uncomfortable for those who occupy that part of the room. Various methods for overcoming this difficulty have been considered by the building industry, but one which has attained considerable usage is the insulation of the slab edges exposed to the outside temperature. A systematic study, recently completed by Harold R. Martin, P. R. Achenbach, and R. S. Dill of the NBS under the sponsorship of the Housing and Home Finance Agency, has shown that edge insulation does in fact reduce cooling at the exposed edges of the floor slab, and has provided quantitative data on the relative merits of different methods of edge insulation.

Using a special structure, with necessary refrigerating apparatus and auxiliary equipment, nine concrete-slab floor specimens were subjected to temperature conditions simulating those to which such floors in basementless houses are exposed during cold weather. The exposed edges of the several specimens were insulated in different ways to determine the effect of eight methods of edge insulation on floor-surface temperature and the possibility of condensation. With a simulated outdoor temperature of about 0° F, the temperature of the floors with edge insulation was found to range from 9 to 13 degrees F higher at a point 1 in. from the cold wall and the average temperature of the 30-in. border next to the cold wall was from 3 to 5 degrees F higher than that of the floor without edge insulation. The tests showed that condensation, which probably would occur on uninsulated floors under certain conditions, can be prevented with edge insulation.

**Exterior view of the special insulated test structure used by NBS for an investigation of edge-insulation methods for concrete-slab floors. The structure was divided lengthwise into two compartments by an "outside" wall—one floored with different edge-insulated concrete slabs and heated to simulate house temperatures, the other not floored and refrigerated to an "out-of-door" temperature of 0° or 32° F.**

For the tests, the insulated test structure was divided lengthwise into two nearly equal compartments by an insulated partition representing an outside wall. One of these compartments was heated and the other cooled. There were no windows in the structure, and each compartment was made accessible by a refrigerator-type door. The cold compartment, simulating the ground outside a home, was not floored.

The floor of the heated compartment consisted of seven concrete slabs parallel to each other and perpendicular to the insulated partition. Each was about $4\frac{1}{2}$ ft in width and $6\frac{1}{2}$ ft in length. Five of the slabs were used either as a control without edge insulation or as test panels with edge insulation, while the slab at each end was used as a guard for the test specimens. All slabs either abutted the footings or were supported by the footings beneath the dividing partition that represented the outside wall. It was at this edge of the test slabs that various insulation methods were applied. Each panel was insulated from the adjacent panels and from the outside of test structure. In every case the concrete slabs were separated from the ground underneath by a fill of gravel or clay tile.

The heating equipment, designed to produce and maintain temperatures simulating those in a house, warmed the floor-slab compartment almost entirely by convection and produced nearly uniform temperatures over all of the floors. The cooling equipment provided approximately uniform temperatures in the cold compartment, with a minimum of air motion opposite the edges of the test floors and at ground level—the zones of principal interest.

Temperatures in the warm compartment were measured with copper-constantan thermocouples placed in a vertical plane passing through the center line of each floor specimen at various selected levels ranging from 30 in. above floor level to 40 in. below floor level. Cold compartment measurements were made with the same type of thermocouple in the air space close to the edge insulation, at ground level, and at selected points down to 28 in. below ground level.

Four tests were made over a period of 2 years, each ranging in duration from 25 to 37 days. Simulated outdoor temperatures of 0° and 32° F were maintained during separate tests in each of the 2 successive years. The first and second tests were made on four specimens with fiberboard edge insulation and on a fifth specimen with no insulation, whereas tests 3 and 4 were made using rubber board on four slab edges while one of the original floor specimens remained intact for comparison with the first year's tests. The fiberboard had a thermal conductivity of about 0.37 Btu/(hr) (sq ft) (deg F/in.) and was dipped in a coal tar mastic; the rubber board had a thermal conductivity of about 0.25 Btu/(hr) (sq ft) (deg F/in.).

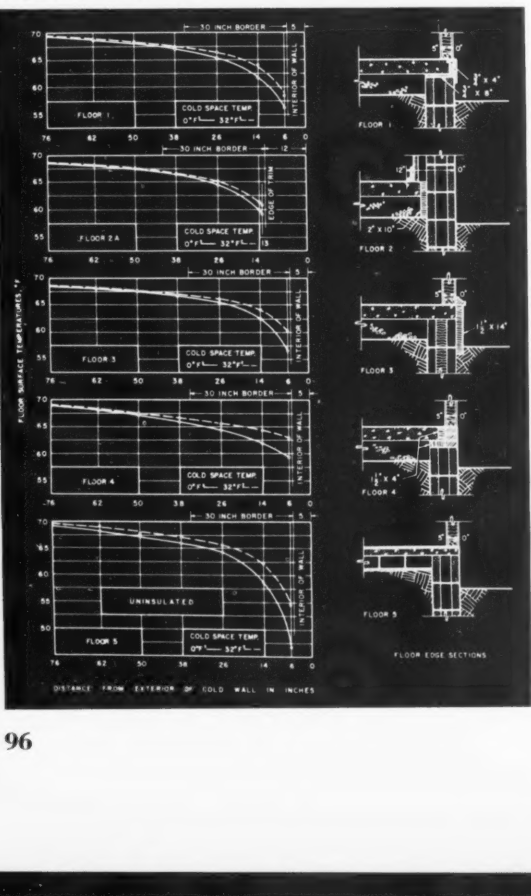



TABLE 1.—*Comparison of floors based upon the difference ($\Delta T$) between the temperature at the 62-inch reference station and the average temperature for the 30-inch border adjacent to the cold wall*

| Order of preference | Cold-space temperature 32° F | | Cold-space temperature 0° F | |
|---|---|---|---|---|
| | Floor and type of edge insulation | $\Delta T$ | Floor and type of edge insulation | $\Delta T$ |
| 1 | 6 (rubber board) | 2.4 | 2A (fiber board) | 4.1 |
| 2 | 2B (fiber board) | 3.0 | 6 (rubber board) | 4.5 |
| 3 | 9 (rubber board) | 3.2 | 2B (fiber board) | 4.6 |
| 4 | 4 (fiber board) | 3.4 | 9 (rubber board) | 4.9 |
| 5 | 8 (rubber board) | 3.4 | 3 (fiber board) | 5.0 |
| 6 | 3 (fiber board) | 3.5 | 4 (fiber board) | 5.1 |
| 7 | 7 (rubber board) | 3.5 | 8 (rubber board) | 5.2 |
| 8 | 2A (fiber board) | 4.0 | 7 (rubber board) | 5.8 |
| 9 | 1 (fiber board) | 4.5 | 1 (fiber board) | 5.8 |
| 10 | 5 (uninsulated) | 6.2 | 5 (uninsulated) | 9.1 |

To determine the approach to steady state conditions of heat transfer, readings were made daily of floor-surface temperatures, subsoil temperatures, and other pertinent temperatures. Such readings showed that the temperatures on the floor surfaces and on the ground surface decreased very little after 10 days and at 25 days the temperatures 40 in. below the floor surface and at the same level in the cold space, 28 in. below the ground surface, had almost reached equilibrium. The results also revealed that the temperature in the cold space had very little effect on the floor-surface temperatures at distances greater than 38 in. from the exterior wall. However, the effect of the cold space temperature was significant at a distance of 14 in. from the exterior of the cold wall.

**Floor-surface temperatures on the 18th day of the tests of concrete flood specimens #1 through #5. (Floor temperature is plotted against the distance from the exterior of the cold wall for both "outside" conditions of 0° and 32° F. The floor-edge design for each specimen is shown to the right of the appropriate graph.)**

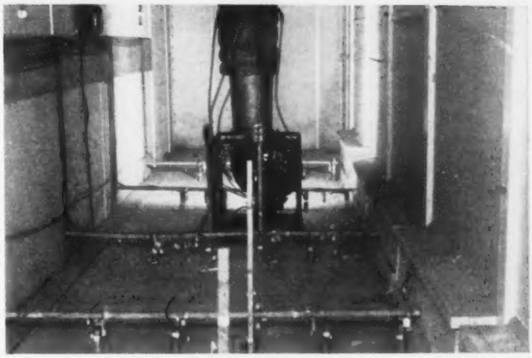
Because the temperature of the air over the floors in the test space varied somewhat for the four tests, the various specimens were compared on the basis of the difference in floor-surface temperature between the station 62 in. from the cold wall and the average temperature on the 30-in. border adjacent to the cold wall. As shown in table 1, when the cold space temperature was maintained at 0° F this temperature difference ranged from 4.1 deg F to 5.8 deg F for the insulated floors and was 9.1 deg F for the uninsulated specimen. Of the insulated floors, the slab insulated with a vertical piece of rubber board 2-in. thick and 18-in. deep (Floor 6) had the warmest border and the specimen with fiberboard $^{3}/_{4}$ in. thick at the slab edge and between slab and footing (Floor 1) had the coldest border.

The floor-surface temperature near the interior of the cold wall was of particular significance insofar as surface condensation on the floors was concerned. Condensation was observed on the floor with the uninsulated edge, but did not occur on any of the floors with insulated edges. The floor surface temperature observed at the edge of the uninsulated floor when the

cold space temperature was 0° F was such that condensation would occur for relative humidities above 44 percent in a 70° F room. Condensation would not have occurred on the poorest of the insulated floors until a relative humidity of 59 percent was reached in a 70° F room under corresponding cold space temperatures.

The greatest danger of condensation occurring on concrete floors would probably occur in modern houses designed for low rates of air infiltration or in those with automatically controlled humidity. However, published information on the wintertime humidities in houses and the temperatures observed during these tests show that it is improbable that condensation would occur on concrete floors with edge construction like any of the insulated specimens tested.

*For further technical details, see* Effect of edge insulation upon temperature and condensation on concrete-slab floors, *by Harold R. Martin, Paul R. Achenbach, and Richard S. Dill, NBS Building Materials and Structures Report 138, obtainable from U. S. Government Printing Office, Washington 25, D. C. Price 20 cents.*



**Inside view of heated compartment of the test structure showing floor specimens, wall construction, and the heating system which was designed to provide uniform temperatures over all test floors. For a particular test series, seven test concrete slabs (four are visible) either abutted or were supported by the footings beneath the "outside wall" (right). It was at this edge that various insulation methods were applied. Each panel was insulated from the adjacent panels.**

# Dimensional Changes in Dental Amalgam

ALTHOUGH SILVER ALLOY amalgams have been widely used in dental restorations for over a hundred years, the metallurgical processes involved in the hardening of these materials have never been completely understood. This is particularly true of the reactions responsible for the dimensional changes which occur during and immediately following solidification. Recently a new approach to the problem was made at NBS. Through use of X-ray diffraction techniques at low temperatures, the dimensional changes were correlated with the presence of uncombined mercury in the alloy after its initial hardening. From the data obtained, a basic mechanism for the dimensional changes has been proposed.

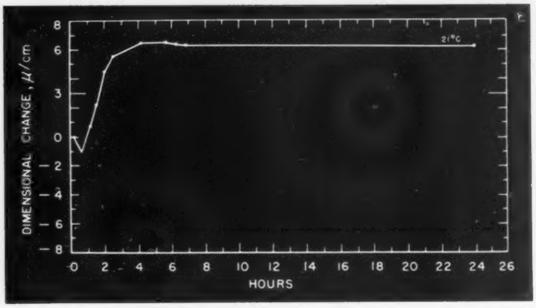
The work was done as part of the program of dental research which the Bureau is conducting in cooperation with the American Dental Association and the dental services of the Army, the Air Force, the Navy, and the Veterans' Administration. The increased understanding which has been brought to the problem should provide a basis for development of improved types of dental amalgams and better methods for their application.

The silver-tin-(copper-zinc) [Ag-Sn-(Cu-Zn)] [1] amalgam used in dentistry is prepared for insertion in a tooth cavity by mixing from 3 to 4 parts of mercury with 2 parts of a powdered alloy containing approximately 70 percent of silver, 25 percent of tin, 0.6 percent of copper, and 0.2 percent of zinc. The resulting plastic mix is divided into small segments, excess mercury is removed from the segments by finger pressure, and each segment is then packed into the cavity. The compositions of dental amalgam alloys have been empirically adjusted so that as the amalgam hardens it expands slightly and locks the restoration into the tooth.

A great deal of experimental work has been done on dental amalgam by many investigators. It has been shown that the dimensional changes occurring after the mixing of the alloy wth mercury depend upon a number of different factors, such as the composition of the alloy, the alloy-mercury ratio, the method of mixing and packing in the tooth, and the temperature. However, until now no satisfactory mechanism has been proposed to explain the initial contraction, subsequent expansion and final contraction of the amalgam which take place within the first 24 hours after amalgamation. Attempts to describe these changes in terms of mercury content have been unsuccessful because chemical analyses could not distinguish between combined and uncombined mercury. X-ray diffraction studies have been made, but the data obtained in this way gave no information on the possible presence of uncombined mercury at various stages of the process since at room temperature the free mercury in the amalgam has no crystalline structure.

To determine the role, if any, of uncombined mercury in the dimensional changes of the amalgam, the Bureau therefore began a study of dental amalgam by X-ray diffraction methods at liquid nitrogen temperatures. In this temperature range any uncombined mercury would be in the solid state and would thus have a crystalline structure. The investigation was carried out by Lt. J. A. Mitchell (a guest worker from the U. S. Navy Dental Corps), and I. C. Schoonover, George

[1] *The elements in parentheses are not always present in this amalgam.*




Typical curve showing the dimensional changes which occur during the hardening of dental amalgam at 21° C.

Dickson, and H. C. Vacher of the NBS staff. It sought to answer three questions: (1) Is uncombined mercury present after the amalgam has hardened? (2) If uncombined mercury is present, does it continue to take part in any reaction? (3) If so, can the dimensional changes which occur in hardened amalgam be correlated with this reaction?

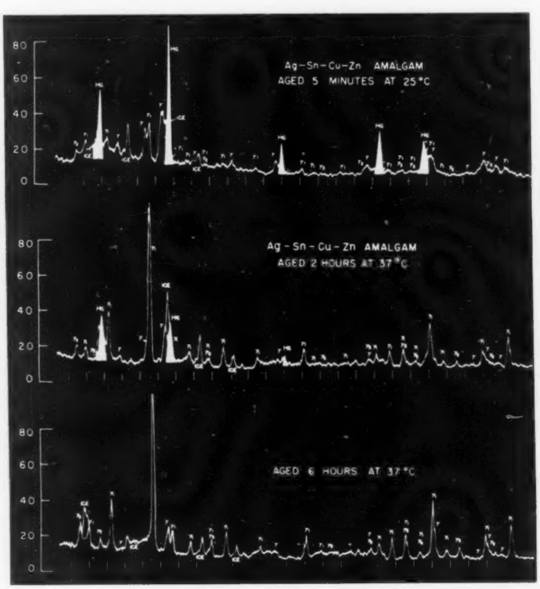
Specimens were prepared by mixing mercury and amalgam alloy, and then packing the resulting mass in a stainless steel combination mold and specimen holder. The procedures used paralleled the methods of clinical dentistry as closely as possible. The steel mold was enclosed in a cylindrical chamber which could be alternately cooled to −125° C by admission of liquid nitrogen and warmed to mouth temperature (+37° C) by a resistance coil. Temperatures were measured with an iron-constantan thermocouple. The condensed amalgam specimen was kept in the mold and was attached immediately to the shaft of a high-angle spectrometer goniometer. Introduction of liquid nitrogen into the chamber surrounding the mold reduced the temperature of the amalgam specimen below the solidification point of uncombined mercury, and this low temperature was kept constant while an X-ray diffraction chart record was made. The specimen was then warmed to mouth temperature and maintained at that temperature for a specific aging period, after which the process was repeated. This alternate freezing and warming of the amalgam specimen was continued for 24 hours in order to follow any chemical changes which might occur. Meanwhile, the corresponding dimensional changes on comparable specimens were observed on a dental interferometer kept in a temperature-controlled air bath.

Analysis of the X-ray diffraction charts showed that uncombined mercury was present in the amalgam and that this mercury disappeared with time, as indicated by the reduction in the height of the mercury lines. The decrease in uncombined mercury was accompanied by a disappearance of the lines representing the original alloy particles and an increase in the alloy-mercury phases of $Ag_2Hg_3$ and $Sn_7Hg$. The data show almost complete disappearance of the mercury lines within 6 hours, a period corresponding generally to the time during which expansion and contraction of amalgams are commonly observed.

From the NBS data, it appears that the initial shrinkage observed during the hardening of amalgam results from the reaction of mercury with the alloy to form compounds having a smaller volume than that of the original alloy and mercury together. The subsequent expansion is caused by diffusion of uncombined mercury throughout the material, and the final shrinkage then results from combination of this mercury with existing phases or with residual alloy. On the basis of this explanation, a reduction in the size of the alloy particles or a heat treatment which would make the particles more reactive would tend to cause a reduced expansion or even a net shrinkage of the amalgam.

The mechanism proposed by the Bureau might well account for the undesirable shrinkage of amalgam which occurs from excessive grinding or working of the material when it is being packed into a cavity. Such treatment would tend to reduce the amount of uncombined mercury, either by furnishing new reactive surfaces or by actual mechanical removal of the mercury. It would also tend to distribute the uncombined mercury throughout the amalgam so that there would be fewer mercury-rich areas from which diffusion could take place.

*For further technical details, see* Some factors affecting the dimensional stability of the Ag-Sn-(Cu-Zn) amalgams, *by J. A. Mitchell, I. C. Schoonover, George Dickson, and H. C. Vacher, J. Research NBS* **52**, *185 (April 1954).*




**X-ray diffraction patterns suggest possible explanation of dimensional changes which take place in dental amalgam during first 6 hours after mixing. Note gradual disappearance of uncombined mercury (sharp white peaks) and of lines representing original particles ($\gamma$). Note also corresponding increase in alloy-mercury phases of $Ag_2Hg_3$ ($\gamma_1$) and $Sn_7Hg$ ($\gamma_2$).**

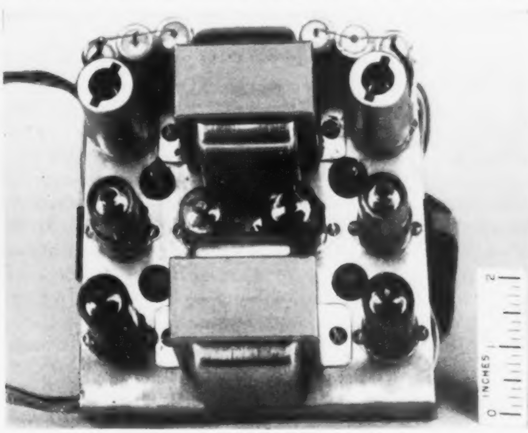
# A Direction-Sensitive Electronic Counting Device

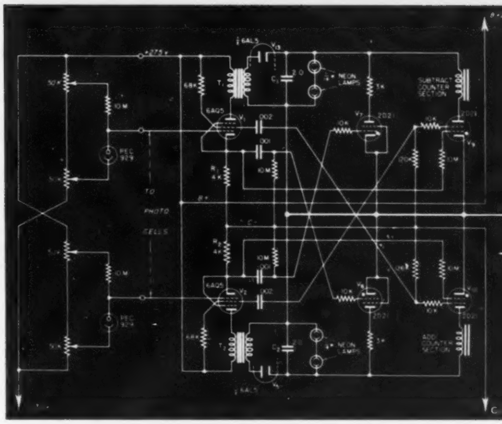
AN ELECTRONIC COUNTER that keeps a separate count of objects passing in either direction has been devised by M. Belfield, P. Franklin, and O. Spokas [1] of NBS. This direction-sensitive circuit offers the following advantages: Low cost, small size, nearly silent performance, and nonstringent power supply requirements. The highest counting speed of this circuit is approximately 180 units per second with an electronic counter, or 35 units per second with an electromechanical counter.

The detecting element of this counter is a pair of photocells placed closely together. The order in which the photocells are activated determines which of the two counter coils—the "add" or the "subtract"—is energized. In operation, an object passing through the counting zone produces four distinct states within the counter. First the object extinguishes the light to one photocell and then the light to the other. As the object moves on, the light to the first photocell is restored, and finally the light to the second photocell is restored.

The circuit consists essentially of a symmetrical arrangement of three pairs of tubes and a pair of storage capacitors. Each of the first pair of tubes (type 6AQ5) detects the input signal from one of the two photocells and charges a storage capacitor through a transformer-diode combination in the plate circuit. These tubes also transfer inhibiting and activating signals to the second and third stages. The second pair of tubes, type 2D21 thyratrons, are used to discharge one of the capacitors of the first stage. Each of the third pair of tubes, also type 2D21 thyratrons, has a counter coil in its plate circuit. These tubes serve as switches to discharge the appropriate capacitor through either the "add" or the "subtract" counter coil.

Direction-sensitive counter (top view), cover removed.





Circuit diagram for direction-sensitive counter.

Under some conditions, there is a possibility of "fooling" the counter. If the object to be counted interrupts the two light beams, uncovers the first, and then backs out of the area, a false addition count and a false subtraction count will be registered. However, the probability of a unit entering and backing out of the counting zone in this manner is very remote. Moreover, if the light beams are placed closely together, it becames nearly impossible for the object to perform the motion needed for the false count.

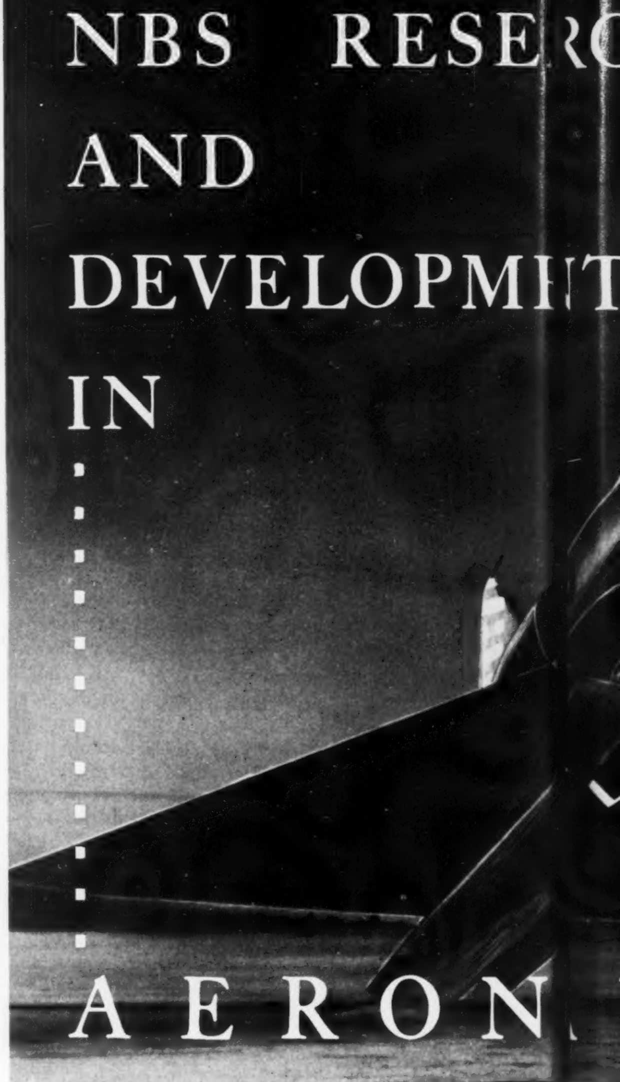
Provision is also made for avoidance of a miscount when a slowly moving object creeps past the counting station. In this case the object might not be counted because the activation of the circuit depends on a surge current from the transformer in the plate circuit for the charging of the capacitor used to operate the relay. If the object to be counted moves through the light beam so slowly that the buildup of the current in the first-stage tube is very slow, the transformer might not be effective in charging the capacitor. However, the choice of a very small beam size excludes the possibility of this type of malfunction. The rate of change of current in the input tube can thus be adjusted so that the capacitor will receive a full charge, even at the slowest rates of object movement through the beam. In trial runs conducted at the Bureau, an object moving as slowly as 9 in. per second was easily registered by the counter. Counts of even slower moving objects can be made through the further improvement of the optical system.

The circuit can be modified to use a recording-type indicator, such as a pen device operated by a rotary relay. Rotary relays of the type used in this application require a larger activating current, operating over a longer period of time than solenoid counters. The necessary energy is obtained through use of additional circuitry to stretch the output pulse from the thryratron in the third stage.

*For further technical details, see* A direction sensitive electronic counter, *M. A. Belfield, Elec. Mfg.*, **52**, *160 (Nov. 1953).*

[1] *Now of the Diamond Ordnance Fuze Laboratories.*

# NBS RESE AND DEVELOPM IN AERON



IN RECENT YEARS progress in aviation has become increasingly dependent upon research and development in the physical sciences and engineering. At every stage in the evolution of a new aircraft and in the design of supplementary equipment, research and development techniques are continually applied. Today, with the current emphasis on airborne defense, industry and government are cooperating in an extremely broad nationwide program of scientific investigation and engineering adaptation directed toward the production of faster, safer, and more reliable aircraft.

As part of this comprehensive effort, the National Bureau of Standards conducts a great diversity of individual projects relating to aeronautics. The scope of the Bureau's functions is broad, embracing major scientific fields of physics, mathematics, chemistry, metallurgy, and various branches of engineering. With this background, the Bureau is frequently called upon to undertake specific research and development projects for the Department of Defense, the Civil Aeronautics Administration, the National Advisory Committee for Aeronautics, and other Government agencies interested in aviation. Examples are current studies of turbulence in supersonic wind tunnels for the NACA and of aircraft lighting for the Navy Bureau of Aeronautics. Also, as custodian of the national standards of physical measurement, NBS carries on research leading to improved methods of measurement and calibration which are often of value in aeronautic instrumentation. Thus work on pressure standards and humidity measurement has been applied to aeronautic barometers, altimeters, and hygrometers.

From time to time the Bureau's facilities for basic investigation into the properties of matter have been utilized to solve problems in aeronautical research. For example, when condensation of the constituents of air became a serious problem in the operation of hypersonic wind tunnels, NBS undertook research on heats of vaporization, phase behavior, and other properties of oxygen, nitrogen, and their mixtures. In addition, much of the information obtained in the Bureau's program on properties of materials—especially plastics, metals, fuel components, and ceramics—is pertinent to aircraft design and has provided a basis for other studies on specific problems of the aircraft industry.

## Aircraft Structures

In the field of aircraft structures, the Bureau has carried on a continuing program for more than 30 years. During this period emphasis has shifted from the early work on rigid airships to present-day structural problems of high-speed aircraft. Currently this program—which is supported by the Navy, the Air Force, and the NACA—is concerned with swept-back and delta-wing configurations and with the effects of aerodynamic heating and vibration.

Efforts have continually been directed toward increased safety and improved performance. For example, a limit load gage was recently developed to provide a simple means for determining whether basic structural components of operational aircraft have been stressed beyond safe limits. Extensive service tests of the gage on high-speed fighter aircraft have proved its value as a safety device and have provided data which suggests that it may find use on other types of aircraft.

Numerous studies of aircraft subassemblies and structures have been made to provide design information for applications where gust and maneuvering loads are unavoidable. In the course of the work, the Bureau has developed theories for computing the stiffness of wings in flutter calculations and has conducted simulated landing-impact tests to check current theories on the dynamic loads in aircraft during landing. Methods have also been devised for determining the properties of the thin sheet material used in aircraft under both compressive and shear loads.

Studies have been carried out for the Navy at elevated temperatures on panels typical of high-speed wing surfaces. These studies provide data needed in the design of supersonic airplanes where aerodynamic heating might seriously reduce strength. Work has also been done on panels having thick sheet, typical of the construction needed in the thin wings of high-speed airplanes. In another project the Bureau has developed methods of analysis for swept-back and delta-wing configurations and has adapted these methods for use with modern high-speed electronic computers.

**Current work of the aircraft structures group has advanced the application of high-speed computer techniques to the analysis of complex aircraft design problems such as arise in delta-wing and sweep-back-wing aircraft. One of the craft studied by the group is the Navy's XF2Y–1 Sea Dart, pictured above. (Official Navy photograph.)**

To provide data needed in the design of aircraft to avoid fatigue failure, a continuing program of fatigue testing of typical aircraft structural components is in progress. In connection with this program, the Bureau is developing instruments to measure fatigue damage to aircraft structures. One of these instruments is a statistical accelerometer for counting the number of bumps to which an airplane has been subjected, while the other is a fine wire designed to fail before the structure and thus to act as a warning indicator.

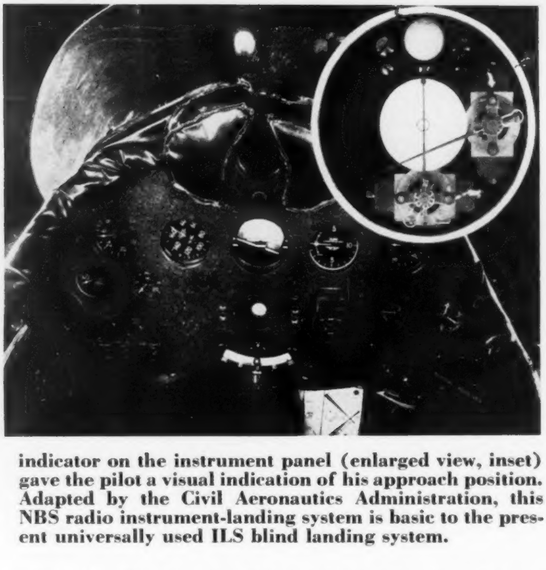
The creep behavior of aircraft joints at moderate temperatures is now being investigated to provide design information for high-speed aircraft in which the skin is heated by air friction. The comparative performance of typical structural adhesives and rivets in aircraft structures has been studied as well as the performance of sandwich panels assembled with adhesives.

## Aerodynamics

In aerodynamics, NBS conducts investigations of laminar and turbulent flow in boundary layers over surfaces, develops equipment for measuring turbulence at speeds up to twice the speed of sound, and studies the nature and effects of turbulence in supersonic wind tunnels. These programs are sponsored by the NACA and the Office of Naval Research.

The mixing action of turbulence in a boundary layer is the controlling factor in the maximum lift of an airplane wing. It is also the factor contributing most to the air friction on the skin of the aircraft. In the boundary-layer work, emphasis is placed on the origin of turbulence and on the mechanics of turbulent motions. Hot-wire anemometers, which respond to small-scale, rapidly changing motions, are used to measure the turbulent motions. The results provide some indication of how and under what conditions turbulence begins, what turbulent motions are, and what the motions do to the flow about a body. Such basic information not only benefits the science of flight generally but also points the way to better aerodynamic shapes for aircraft. In a recent investigation, an attempt was made to learn as much as possible about the nature of turbulent motions by present-day experimental techniques. Laboratory measurements were used in various ways to derive such information as where and in what quantities turbulent motions were produced, and where and at what rate turbulent motions were dissipated by viscosity.

The advent of high-speed flight has made it necessary to measure turbulence in supersonic wind tunnels. A long-range investigation is now being conducted to determine the possibilities of the hot-wire anemometer as a research tool in this field. The factors affecting the cooling of fine heated wires are being investigated in the transonic and supersonic speed ranges. The potentialities and limitations of the instrument are gradually unfolding as studies are made of the sensitivity of wires as small as 0.00005 inch in diameter to air speeds twice the speed of sound.



This Curtiss Fledgling, equipped in 1931 with the first complete system for blind landing of aircraft using a landing beam, demonstrated the practicability of the system by an extensive series of hooded landings at College Park, Md., and Newark, N. J. The dual-pointer landing indicator on the instrument panel (enlarged view, inset) gave the pilot a visual indication of his approach position. Adapted by the Civil Aeronautics Administration, this NBS radio instrument-landing system is basic to the present universally used ILS blind landing system.

## Instrumentation and Equipment

NBS research and development on aeronautic instruments and apparatus is done largely for the Navy Bureau of Aeronautics and the Air Force. The work includes projects on pressure and humidity measurement; aircraft oxygen apparatus; aerological instrumentation for measuring pressure, temperature, and humidity; and the development of selected flight test instruments. Special equipment has been designed for testing hygrometers at temperatures from $-40°$ to $+50°$ C and higher, and an electrical hygrometer with improved performance is under development. In recent years stick- and pedal-force indicators, angle-of-attack indicators, Pitot and suspended static tubes, and pitch- and heel-angle indicators have been developed for the Bureau of Aeronautics to use in flight testing. A research program on corrugated diaphragms has also been undertaken for the Air Force.

Two types of compasses have been worked out in cooperation with the Navy Department. In one of these, eddy-current damping is substituted for the troublesome liquid damping. This compass has been designed to serve as a standby in the event that the electronic types fail and for use on abandoning aircraft over ocean or waste areas. The other is the sky compass, which is based on the work of the late Dr. A. H. Pfund of Johns Hopkins University. The sky compass utilizes the direction of polarization of the light of the sky with reference to the sun. If the clear sky is illuminated by sunlight, even after sunset, the sun's azimuth can be determined by the instrument, and the direction of flight can thus be established. This compass is clearly of importance in polar navigation where the magnetic compass cannot be used.

Recent trends toward high-altitude flight and more efficient utilization of weight and space in aircraft have led to a much wider application of pneumatic systems for performing such high-speed operations as extending and retracting the landing gear, emergency canopy or seat ejection, gun charging, and rocket ejection. To further the development and technical evaluation of pneumatic systems and equipment, NBS, with the cooperation of the Bureau of Aeronautics, has established a pneumatics laboratory equipped with high-pressure, high-capacity facilities. The new laboratory has developed instrumentation to study the pneumatics of high-pressure, short-duration transient flow and is now engaged in the technical evaluation of airborne pneumatic systems and individual components such as actuators, pressure reducers, special-purpose valves, storage reservoirs, and other related equipment. Parallel theoretical and experimental investigations are also being conducted on the physics of phenomena associated with the thermodynamics and mechanics of fluid flow.

## Radio Navigation and Communication

Much of the Bureau's work in the radio field has been of direct assistance to air navigation and communication. In the late 20's and early 30's NBS was engaged in the development of radio aids to air navigation for the Department of Commerce. This period saw the completion by NBS of some of the basic systems upon which present air navigation systems are based. Since about 1928 radio beacons have been used to mark the airways of the United States. The method—involving interlacing signals on two loops of a figure-eight pattern—was first proposed by the Bureau in 1924. Experimental beacons were constructed by NBS, and from this work stems the present worldwide system of radio beacons.

About 1929, NBS scientists proposed and developed a radio guiding beam for instrument landing, and by the end of 1933 they had demonstrated the first complete system for blind landing of aircraft. The system not only increased by a large factor the safety of landings, but also made it possible for aircraft to operate under conditions of visibility that would otherwise have made flight impossible. Adopted and adapted by the Civil Aeronautics Administration, this, the first radio instrument-landing system, is basic to the present universally used ILS blind landing system.

Today the National Bureau of Standards Central Radio Propagation Laboratory, organized as a division of NBS, serves as the primary agency of the Government for research in radio wave propagation and for the centralization and coordination of information in this field. It receives and analyzes data from a widely separated network of ionospheric sounding stations and predicts in advance the best frequencies for use in worldwide radio communication.

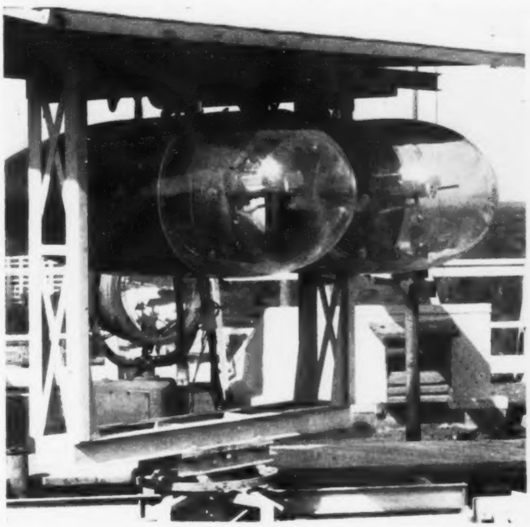
A large part of this program has a direct bearing on aircraft navigation and communication. For example, an important project now under way is concerned with basic propagation research for a unified system of air communication, navigation, and traffic control to operate in the frequency range of 960 to 1,600 megacycles. A comprehensive investigation of the problems involved has been undertaken at the request of the Air Navigation Development Board of the CAA. To determine the necessary propagation factors for the effective allocation and use of these frequencies, NBS has established research facilities at Cheyenne Mountain, Colo. Two powerful transmitters are located at 9,000 and 7,000 ft above sea level. The essentially sheer, 2,000-ft drop from summit to base makes the Cheyenne Mountain site ideally suited for simulating communication between aircraft and ground. Permanent installations on the Colorado and Kansas plains as far away as 300 miles receive the transmitted signals and study their variations.

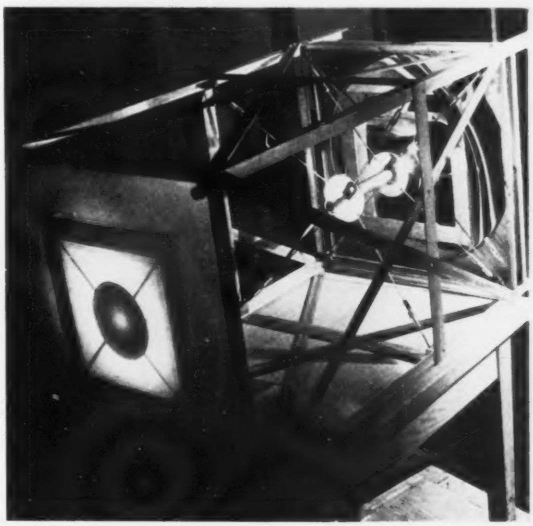
NBS establishes, develops, and maintains standards and methods of measuring electrical quantities throughout the ranges of radio and microwave frequencies. Included are standard time and frequency signals which are broadcast continuously by the Bureau's radio stations at Beltsville, Md., and in Hawaii. Standard-frequency broadcasts are important in keeping all kinds of radio, radar, and electronic equipment properly tuned throughout the world. This service is required in international transportation and communicatioins so that, for example, an airplane with radio navigational equipment will be on the right frequency wherever it is in the world and whatever airport it is using.

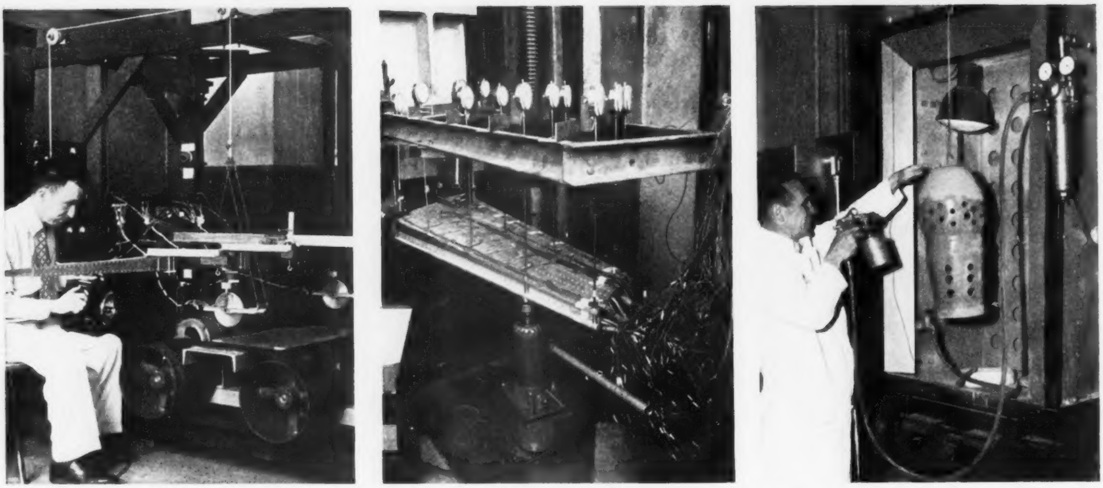
## Aviation Lighting and Visibility

Aviation lighting has long been an active field at NBS. The Bureau has assisted the Civil Aeronautics Administration in development and evaluation of approach-light systems from the time these lights were first considered. Similar work has been the development of airway beacons and course lights and of position lights—formerly called navigation lights—which

**Left: Airborne searchlights mounted on a roof at the Bureau for comparative evaluation of different types of lamps and optical systems.**
**Right: Apparatus designed and constructed at the Bureau for focusing aircraft searchlight reflectors and determining their quality. An opaque mask is mounted in front of the reflector at the far end of the apparatus, and an extremely small lamp is placed near the focal point of the reflector on the axis of the apparatus. Examination of the shadow pattern on the screen at left permits adjustment of the lamp for proper focus and reveals clearly imperfections in reflector quality.**







**_Left:_ A dynamic model of a "four-engine airplane" is used to evaluate present design theory of large airplanes in regard to transient vibration arising from landing impact. The model wing, consisting of a tapered box beam, was built to give a typical distribution of mass and flexural rigidity proportional to that of a well known transport plane. The fuselage is equipped with a model alighting gear whose behavior can be changed over a wide range. The belting passing over the large wheels at the bottom simulates an airport runway moving with respect to the aircraft. _Center:_ The stress distribution of a swept-back wing specimen under load is determined. The many wires lead from electric strain gages distributed about the specimen, and the dial gages measure the deformation. _Right:_ Ceramic specialist applies an NBS high-temperature ceramic coating to a jet-engine combustion liner in preparation for a test in a J–48 engine. Here the coating slip is being sprayed on the outer surfaces of the liner.**

are used to identify the course and position of aircraft to other aircraft. In addition to a continuing program on civil aviation lighting devices for the CAA, NBS cooperates in the international coordination of specifications for the colors of aviation signal lights, does work for the Weather Bureau on the determination of visibility at airports, and carries on a series of projects for the Navy Bureau of Aeronautics.

Accurate measurement of ceiling and visibility is often an important element in safe landings. During periods of restricted visibility, electronic aids are used to bring aircraft sufficiently close to the runway so that visual aids may be used to complete the landing. However, measurements taken at a weather station sometimes as much as 2 miles away do not always give a true picture of the runway conditions. For accurate measurements of the ceiling along the active runways, NBS developed the ceilometer for the Weather Bureau several years ago. The transmissometer, an instrument for measurement of visibility in landing areas, was later developed by NBS under the sponsorship of the CAA, the Navy Bureau of Aeronautics, and the Air Force. During tests remote-recording equipment installed on these instruments provides a continuous record of the ceiling and visibility conditions of fogs in the critical locations. The instruments also give personnel in the control tower a much better idea of the conditions existing throughout the approach zone and along the runway than would be obtained by visual observations.

NBS is now doing work for the Bureau of Aeronautics on aircraft lighting, aviation ground lighting, visual range meters, and visual landing aids. Projects under aircraft lighting include development and evaluation of antisubmarine searchlights, instrument and control panel lighting devices, and cockpit lighting control systems. In connection with aviation ground lighting work, the kinorama—a device that enables a pilot to evaluate a system of approach lights without leaving the ground—was developed; its use in training pilots is now being studied. Important contributions to naval aircraft lighting include the development of the individual instrument lighting fixture, improvements in interior red lighting for maintenance of dark adaptation, continued improvement in searchlight operation, and standardization of the colors of identification lights.

Other NBS projects in the general field of optics are concerned with the design of lenses for use in reconnaissance and mapping from airplanes. Under the sponsorship of the Air Force, automatic computing machines are being used for experimental designs of extremely wide-angle lenses and also for lenses of high numerical aperture for night photography. Currently NBS is providing technical supervision of an Air Force contract with private industry for the investigation and development of production techniques to be applied in the manufacture of large optical elements of high quality. This glass will be used for camera lenses for high-altitude photoreconnaissance, for wind-tunnel optics, and for other critical Air Force applications.

# Aircraft Engines and Fuels

Although gas turbines and jet engines are being increasingly utilized, particularly by the military services, much research and development remain to be done on components in order to attain the desired reliability, economy, performance, and safety. In this field the National Bureau of Standards is concerned with problems of burning gaseous mixtures, of fuel handling and metering, and of determining the composition and temperature of the products of combustion in gas turbines and other air-breathing jet engines.

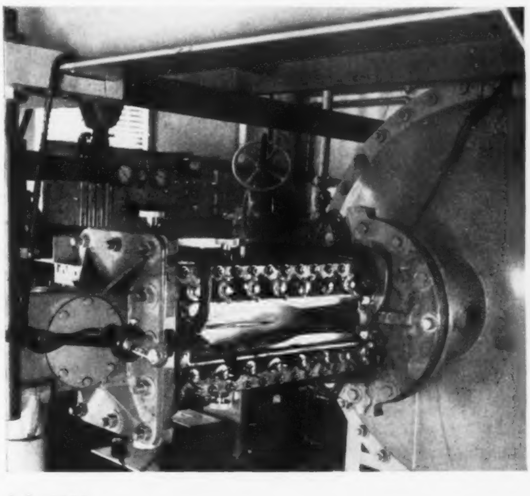
A continuing program of combustion research, sponsored by the Navy Bureau of Aeronautics since the beginning of the last war, includes both basic and applied studies of burning velocities, flame temperatures, gas sampling and mixing, and the development of design and performance data on combustors for turbojets, ramjets, and afterburners. Another phase of the work for the Bureau of Aeronautics is concerned with the development, evaluation, and improvement of test equipment for the components of aircraft fuel systems. Original emphasis on carburetors has since shifted to the corresponding parts of turbojet engines, and a hydraulically driven test bench for jet fuel-control units is now under development. Still other projects, sponsored by the Air Force, deal with conventional and spectroscopic methods for measuring the temperature of hot gases flowing at high velocities, and with low-voltage high-energy ignition systems for turbojet engines.

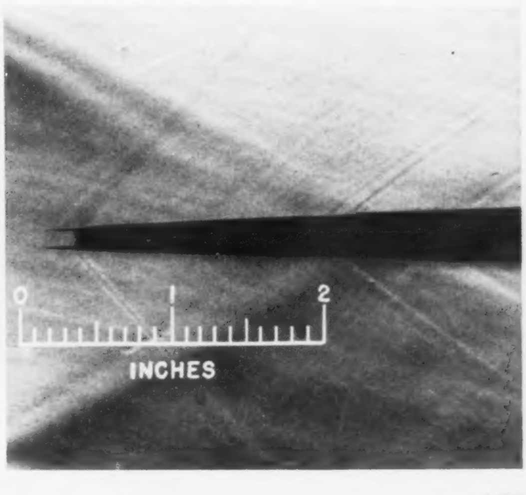
Much of the current work of NBS on thermal properties of gases has been undertaken to provide accurate thermal data on the gases which flow through jet engines or wind tunnels, or which an aircraft must encounter in the atmosphere. With the cooperation of the NACA, the Bureau recently completed calculation and compilation of 100 tables giving the thermodynamic and transport properties of such gases as oxygen, nitrogen, hydrogen, carbon dioxide, carbon monoxide, argon, and steam from low temperatures and pressures to 3,000° K and 100 atmospheres. Work in this general field is continuing. Included are projects sponsored by the Bureau of Aeronautics on the thermodynamic properties of air and the heats of combustion of jet fuels. Other projects are concerned with the determination of the temperature of very hot gases and a study of the thermal conductivities of jet-engine exhaust gases.

Basic work on the problem of knock in reciprocating engines has been conducted for several years. The relationship between the structure of hydrocarbon fuel molecules and their tendency to knock was developed from measurements on several score of very pure hydrocarbons synthesized at the Bureau. This work provided some of the basic information needed for development of high-octane fuels. Investigations of the relation between structure of the fuel and its burning velocity, combustion efficiency, heat of combustion, and other properties of interest in connection with jet fuels were also made possible by contributions of Bureau-synthesized hydrocarbons. The actual mechanism of the chemical reactions taking place in combustion and their effect on knock are now being studied in three separate projects. Developments in this field include new and improved instrumentation; an example is a device that will extract an analytical sample of gas from an engine cylinder in 0.0002 second.

NBS maintains the primary standards for the determination of the octane numbers of both automotive and aviation fuels. With the cooperation of the American Society for Testing Materials, research is carried on to

**Left: Test section of the supersonic wind tunnel at the Bureau. A hot-wire anemometer probe and supersonic blocks may be seen through the transparent window (center). Wind velocities up to twice the speed of sound are obtained in this tunnel. Right: A schlieren photograph of the flow in the test section with the wire probe in place. Note shock waves which appear as light streaks against the grey background.**





increase the accuracy of these standards and to develop improved measuring instruments and apparatus. The Bureau is also responsible for determining and maintaining standards of viscosity. In connection with this activity, basic lubrication studies are conducted on the characteristics of fluids, greases, and bearings for use in mechanical equipment. Recently methods have been developed for the Navy Bureau of Aeronautics which show promise for controlling the anti-wear and load-carrying properties of turbo-prop lubricants.

## High-Temperature Materials

The combustion products in the newer and more powerful aircraft engines—particularly jet engines—are hotter and more destructive than those in the engines of a few years ago. At the same time the enormously increased demand for highly heat-resistant alloy parts has brought about an urgent need for minimizing the strategic metal content of alloys. The application of protective ceramic coatings has made possible the use of heat resisting alloys of much lower strategic-metal content that would otherwise be possible. For example, a coated 18-chromium, 8-nickel steel is now used for jet engine combustion chamber liners instead of a 78-nickle, 14-chromium alloy. Without the coating the lower-alloy part would burn through in a comparatively short operating period.

During World War II, the National Bureau of Standards pioneered development of the first high-temperature ceramic coating for steel to be produced commercially on aircraft parts. This coating was used to protect mild steel exhaust stacks which, if uncoated, would have required a heat-resisting alloy with substantial content of strategic metal. Since the war the Bureau, working under NACA sponsorship, has developed coatings for heat resisting alloys that are required to withstand considerably higher operating temperatures than could be met by mild steel, even when coated. These coatings were first used extensively on heat exchangers for large bombers, and subsequently on an expanding list of items including jet engine combustion chamber liners and nozzle boxes for turbosuperchargers. More than a score of companies are now producing the coatings and finding new uses for them. Estimated savings to the Government run to several millions annually.

With the support of the NACA, Air Force, and Army Ordnance, the Bureau is also conducting studies of the adherence of ceramics to metals, the effects of ceramic coatings on the creep behavior of metallic single crystals; the erosion behavior of aircraft components as affected by ceramic coatings; and the factors affecting electrical resistivity of ceramic coatings at elevated temperatures, with special reference to insulation of electronic components.

Under Air Force sponsorship, the Bureau is now studying cermets for turbine blade use and as flameholders for afterburners in jet planes. Other current investigations deal with special refractory porcelains for possible use under severe high-temperature condi tions as nozzles for rockets and turbine blades.

## Aircraft Plastics

Work on transparent and laminated plastics, dopes, and coatings for aircraft use has been conducted by NBS for the Navy Bureau of Aeronautics since 1933. This program contributed to the initial adoption of acrylic plastic glazing for aircraft and the increased use of laminated plastics for accessories and semi-structural parts. The dope and many of the coatings now used on Navy airplanes are based on the results of NBS investigations. Current work for the Bureau of Aeronautics is concerned with the development and application of new methods for evaluating plastics and promising coating materials, and a survey of the properties of transparent plastics.

With the increasing use of laminated plastics in aircraft, a need has developed for more comprehensive information on the properties of these materials in order to evaluate them for aircraft application and to prepare suitable specifications. To provide the necessary data, NBS has conducted an extensive program, sponsored by the NACA, on the properties of plastic laminates. Studies have been made of the effect of simulated service conditions, fuel immersion, and extreme temperatures on these materials.

Under the sponsorship of the NACA and the Air Force, NBS has undertaken a number of different investigations of glass-fiber reinforced plastics, which the Armed Forces have found adaptable to radomes and other parts of aircraft. It has been shown that close control of the many variables involved in production makes possible the fabrication of reinforced plastics with more uniform quality, greater strength, and improved electrical properties.

The crazing of the acrylic plastic glazing used in aircraft canopies has been a major problem to the industry for some time. Under NACA sponsorship, NBS is now engaged in a fundamental investigation of the nature of the crazing process and the conditions under which it occurs. Recently this work has shown that by hot-stretching the acrylic plastic sheets the material can be made essentially craze-resistant, taking on a laminar structure which gives it improved resistance to bursting when subjected to bullet impact while pressurized.

In aeronautical applications, textiles, plastics, and other organic materials are often subjected to shock loading at widely varying conditions of temperature and relative humidity. The stresses and strains thus developed within the material and their propagation through it are important in the evaluation of these materials for aircraft use. The Bureau is now constructing equipment for the classification and evaluation of textile fibers, yarns, cords, fabrics, and plastics under very high rates of deformation. A new and simple approach will be used involving determination of the "critical velocity" required to rupture the specimen.

## Aircraft Metals

A large part of the Bureau's work in metallurgy has been specifically centered on aeronautical problems. Studies of the corrosion of aircraft alloys—aluminum, magnesium, stainless steel, titanium, and others—have been carried on for the Navy Bureau of Aeronautics since 1925, providing results of basic importance in aircraft design. During this period NBS has evaluated the corrosion resistance of most of the light-metal alloys used in aircraft.

When metallic-skin structures were introduced in the early twenties, they were at first unsuccessful because intergranular corrosion caused early failure of the metals used at that time. However, investigation of various types of heat treatment for aluminum alloys at the Bureau soon resulted in the development of a "cold water quench" procedure which greatly reduces this type of corrosion. Later, a chromic acid anodizing process, more rapid and less expensive than the British method, was worked out to protect aluminum alloys from corrosion. This process is now used on all Naval aircraft. Considerable work has also been done on the stress corrosion resistance of aluminum and magnesium alloys to determine their suitability for use in Naval aircraft. As new alloys and coatings or other protective processes are developed, the Bureau continues to evaluate them to determine their suitability for aircraft use. The effects of manufacturing and assembling processes—such as riveting, welding, and dimpling—are also studied.

A variety of other metallurgical investigations are carried on for the Bureau of Aeronautics. Failed parts are regularly submitted to NBS by the Navy for examination and diagnosis of the cause of failure. Some years ago a study was made to determine the effect of low temperatures on various aircraft materials. During World War II a number of the "national emergency" steels were evaluated for aircraft applications. More recent investigations have dealt with the intergranular embrittlement of austenitic stainless steels and the solubility of carbon in these steels. The possibility of making a high-strength structural steel to meet Navy specifications is currently being studied.

The Civil Aeronautics Board and the Civil Aeronautics Administration also calls on NBS regularly for advice with respect to certain types of proposed design changes and for studies of parts that have failed in service. About 20 studies of failed parts are reported to the CAB each year.

## Other Projects

Other phases of NBS work relating to aeronautics include research and development for the Navy leading to improved batteries for aircraft, computation of Loran navigation tables, development of methods for calibrating instruments used in aircraft manufacture and operation, and work on fire detection in aircraft engines and fuselages. During World War II NBS, in cooperation with the Navy, MIT, and the Bell Laboratories, developed the BAT—the only guided missile used successfully in combat by the Allies. Since the war this program (recently transferred to the Department of Defense) has been continued, with emphasis on more advanced forms of guided missiles. A program of electronic miniaturization, sponsored by the Navy Bureau of Aeronautics, has done much to make airborne electronic equipment more compact, simpler and cheaper to produce and maintain, and more reliable.

SEAC (National Bureau of Standards Eastern Automatic Computer) and SWAC (National Bureau of Standards Western Automatic Computer) were developed and constructed under Air Force sponsorship. Both are large-scale superspeed electronic computers of the digital type. SWAC is being used to solve problems of the Office of Air Research and aircraft problems originating with contractors of the Air Force (in particular, the aircraft industry of the West Coast). SEAC is being used for a wide variety of scientific and engineering problems, many of them in the aeronautical field. A third computer, DYSEAC, now under construction for the Department of Defense, has interesting possibilities for use in the automatic control of air traffic at airport terminals.

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## Optical Image Evaluation

*Optical Image Evaluation,* proceedings of the symposium held October 18–20, 1951, National Bureau of Standards Circular 526 is now available. It is the last of 12 volumes covering the symposia held at the Bureau on a wide variety of technical subjects during the NBS Semicentennial celebration.

Other subjects that were treated at the symposia, and which drew scientific papers from all parts of the world, were: *Low-Temperature Physics,* NBS Circular 519 ($2.00); *Mechanical Properties of Metals at Low Temperatures,* Circular 520 ($1.50); *Gravity Waves,* Circular 521 ($2.00); *Mass Spectroscopy in Physics Research,* Circular 522 ($1.75); *Energy Transfer in Hot Gases,* Circular 523 ($1.50); *Electrochemical Constants,* Circular 524 ($2.00); *Polymer Degradation Mechanisms,* Circular 525 ($2.25); *Optical Image Evaluation,* Circular 526 ($2.25); *Electron Physics,* Circular 527 ($2.75); *Characteristics and Applications of Resistance Strain Gages,* Circular 528 ($1.50); *Electrodeposition Research,* Circular 529 ($1.50); and *Simultaneous Linear Equations and the Determination of Eigenvalues,* Applied Mathematics Series 29 ($1.50).

All of the volumes contain figures and tables and are bound in blue buckram. They may be obtained from the Superintendent of Documents, Government Printing Office, Washington 25, D. C.

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# TECHNICAL NEWS BULLETIN

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SINCLAIR WEEKS, *Secretary*
NATIONAL BUREAU OF STANDARDS
A. V. ASTIN, *Director*

**July 1954** **Issued Monthly** **Vol. 38, No. 7**

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# Publications of the National Bureau of Standards

### PERIODICALS

Journal of Research of the National Bureau of Standards, volume **52**, number 6, June 1954 (RP2501 to RP2509 incl.). Annual subscription $5.50.

Technical News Bulletin, Volume **38**, number 6, June 1954. 10 cents. Annual subscription $1.00.

CRPL-118. Basic Radio Propagation Predictions for September 1954. Three months in advance. Issued June 1954. 10 cents. Annual subscription $1.00.

### RESEARCH PAPERS

*Reprints from Journal of Research, volume* **52**, *number 6, June 1954, 70 cents. Single copies of Research Papers are not available for sale. The Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C., will reprint 100 or more copies, and request for the purchase price should be mailed promptly to that office.*

RP2501. Discussion of current-sheet approximations in reference to high-frequency magnetic measurements. Bohdan Kostyshyn and Peter H. Haas.

RP2502. Thermodynamic functions for carbon dioxide in the ideal gas state. Harold W. Wooley.

RP2503. Optical spectroscopic determination of hydrogen isotopes in aqueous mixtures. Herbert P. Broida, Harold J. Morowitz, and Margaret Selgin.

RP2504. Refractive indices of five selected optical glasses. Robert E. Stephens and William S. Rodney.

RP2505. Spectral transmissive properties of five selected optical glasses. Harry J. Keegan, Marion A. Belknap, and Dorothy J. Cordrey.

RP2506. Densities of five selected optical glasses. Charles T. Collett.

RP2507. Thermal expansion of five selected optical glasses. Peter Hidnert.

RP2508. Evaluation of the exponential integral for large complex arguments. John Todd.

RP2509. On nearly triangular matrices. A. M. Ostrowski.

### CIRCULARS

C526. Optical Image Evaluation. Proceedings of the NBS Semicentennial Symposium on Optical Image Evaluation, held at the NBS on October 18, 19, 20, 1951. $2.25.

### PUBLICATIONS IN OTHER JOURNALS

Total-absorption X-ray spectrometry: application to betatron experiments. H. W. Koch and R. S. Foote. Nucleonics. (330 West Forty-second Street, New York 36, N. Y.) **12**, No. 3, 51 (March 1954).

Estimation of correlation coefficients from scatter diagrams. George R. Sugar. J. Appl. Phys. (57 East Fifty-fifth Street, New York 22, N. Y.) **25**, No. 3, 354 (March 1954).

A comparison of amplitude and angle modulation for narrow-band communication of binary-coded messages in fluctuation noise. G. Franklin Montgomery. Proc. IRE (1 East Seventy-ninth Street, New York 21, N. Y.) **42**, No. 2, 447 (February 1954).

Some stochastic problems in wave propagation, Part I. Joseph Feinstein. Proc. IRE (1 East Seventy-ninth Street, New York 21, N. Y.) **42**, No. 1, 23 (January 1954).

Some theorems for partially balanced designs. W. S. Connor and W. H. Clatworthy. (Business Administration, University of Michigan, Ann Arbor, Michigan) **25**, No. 1, 1–0 (March 1954).

Some aspects of the charge and discharge processes in lead-acid storage batteries. D. Norman Craig and Walter J. Hamer. Applications and Industry (33 West Thirty-ninth Street, New York 18, N. Y.) No. 11, 22 (March 1954).

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